

Monkey Microbes and Human Health:

Putting health disparities into an evolutionary context



Katherine R. Amato

Department of Anthropology
Northwestern University

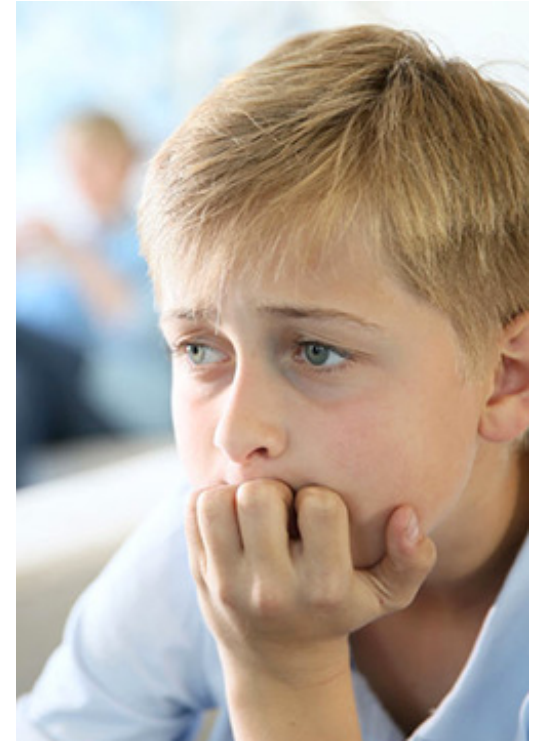
Gut microbiota



Nutrition



Immune function



Mental state

The Gut Microbiota

- Implicated in:
 - Hypertension
 - Asthma
 - Cardiovascular Disease
 - Obesity
 - Cancer
 - And more...



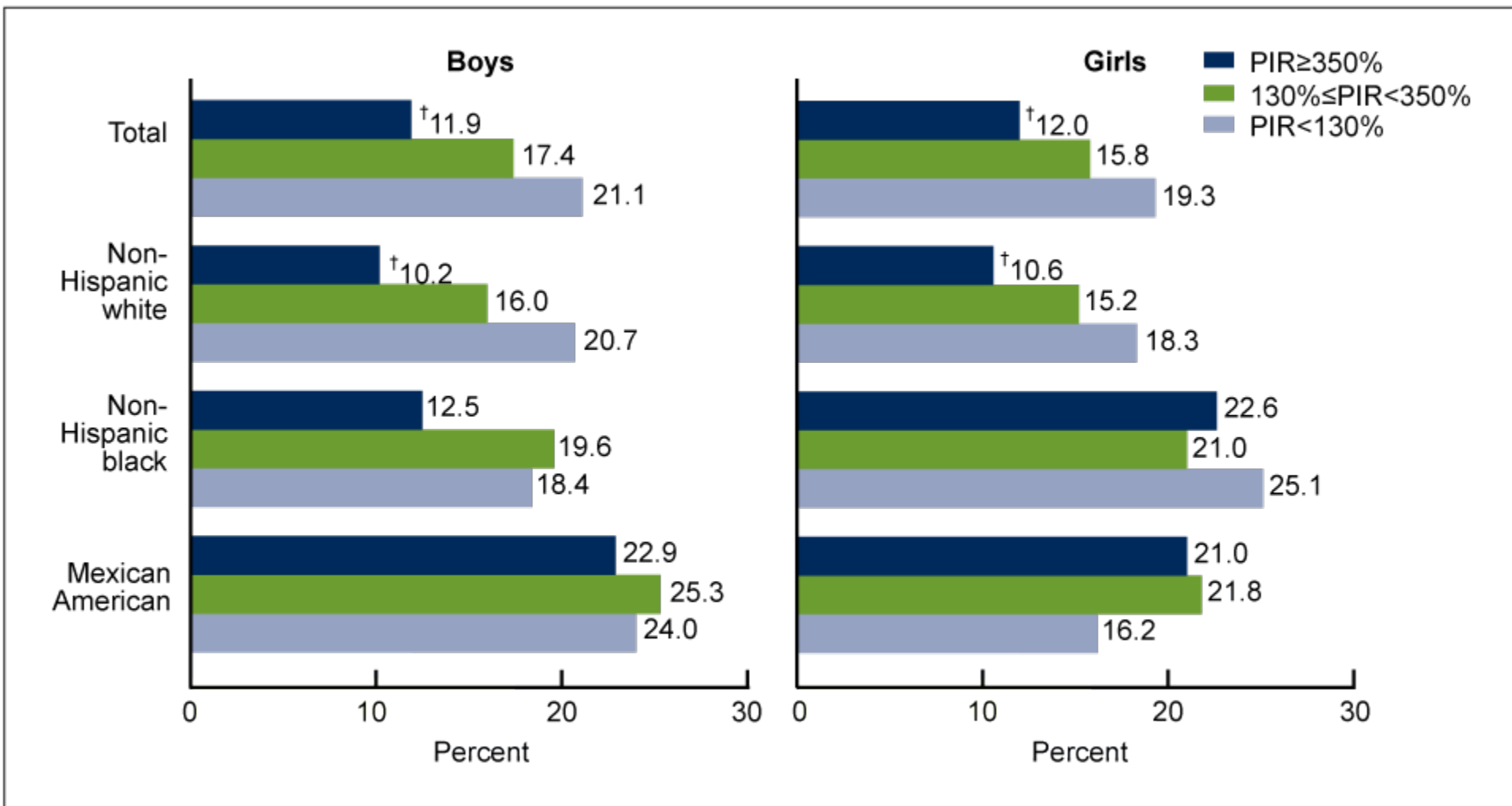
Health Disparities

- Apparent in:
 - Hypertension
 - Asthma
 - Cardiovascular Disease
 - Obesity
 - Cancer
 - And more...



How important are gut microbes for understanding patterns of health inequality across populations?

Figure 1. Prevalence of obesity among children and adolescents aged 2–19 years, by poverty income ratio, sex, and race and ethnicity: United States, 2005–2008



†Significant trend.

NOTES: PIR is poverty income ratio. Persons of other race and ethnicity included in total.

SOURCE: CDC/NCHS, National Health and Nutrition Examination Survey, 2005–2008.

An obesity-associated gut microbiome with increased capacity for energy harvest

Peter J. Turnbaugh¹, Ruth E. Ley¹, Michael A. Mahowald¹, Vincent Magrini²,
Elaine R. Mardis^{1,2} & Jeffrey I. Gordon¹

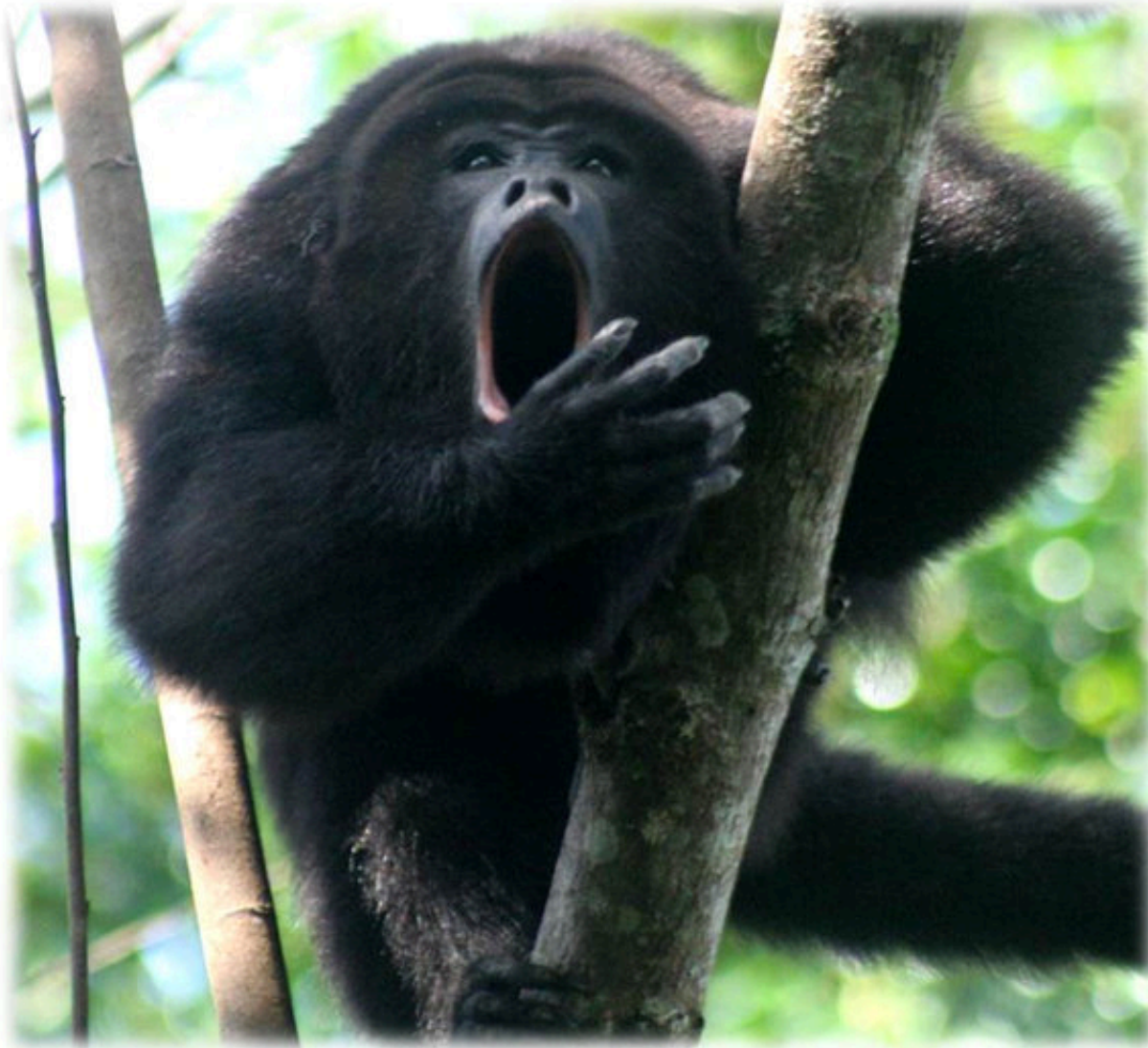


Increased SCFA Production
→ More Energy to Host

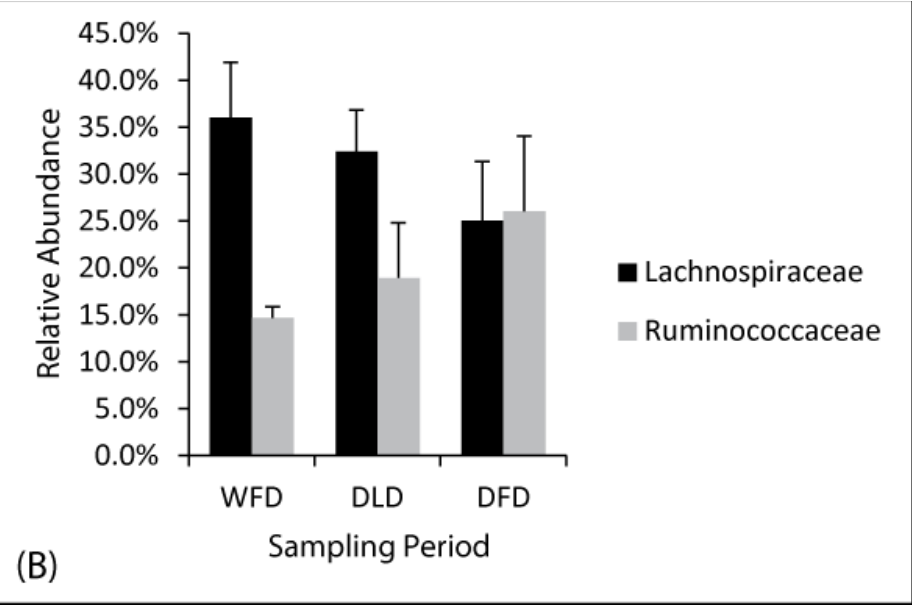
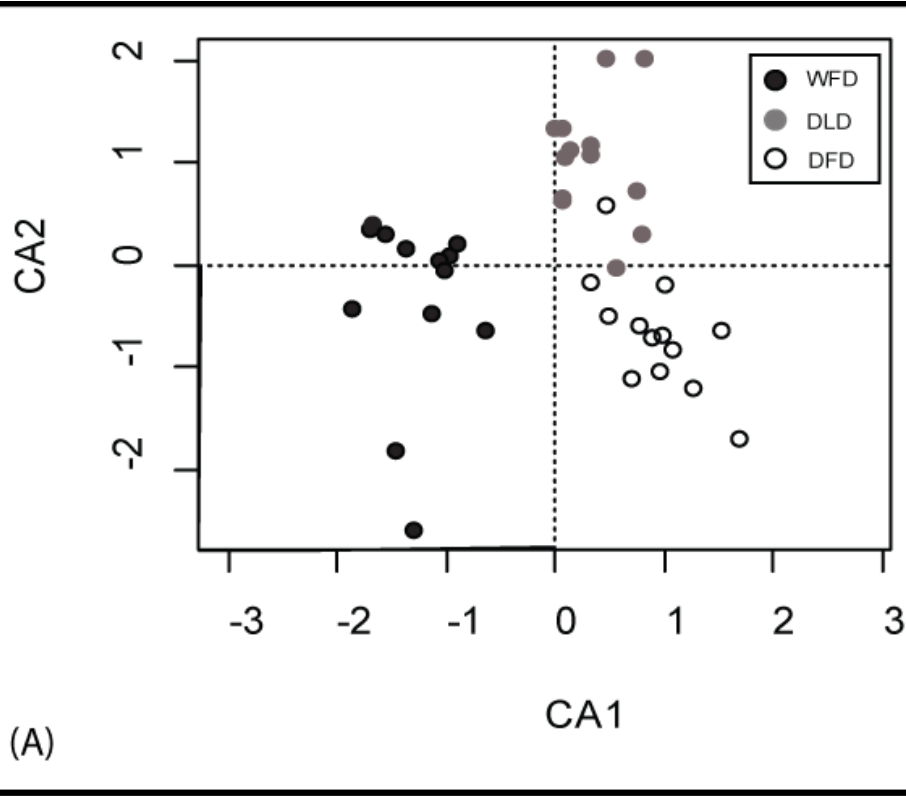








Gut Microbes Compensate Across Seasons



$F_{2,38} = 3.56, r^2 = 0.14, p = 0.0002$

→
Energy Intake ↓

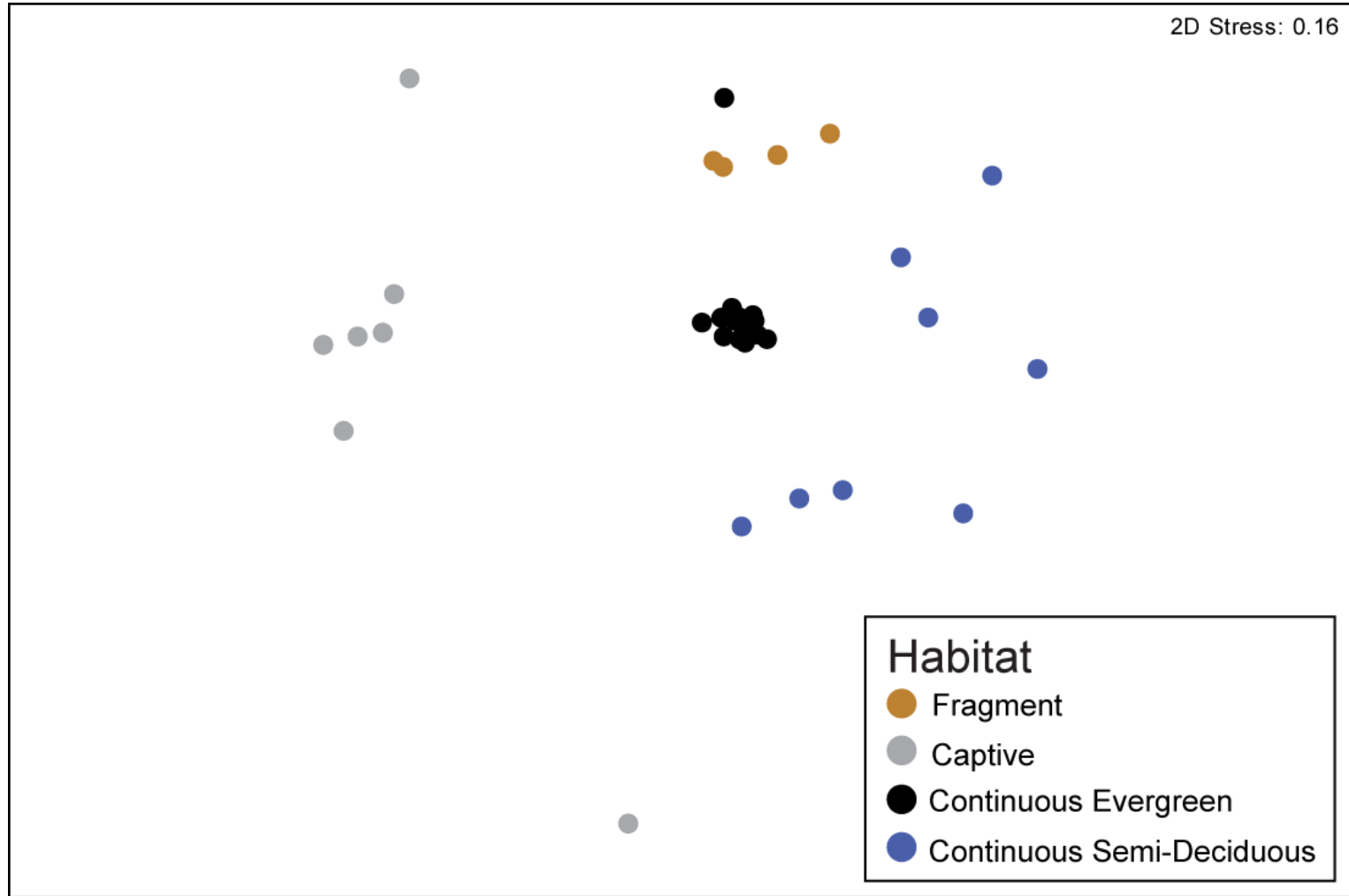
Gut Microbes Compensate For Life History

- Juveniles
 - Characterized by Firmicutes (*Faecalibacterium*, *Roseburia*, *Ruminococcus*)
- Adult Females
 - High Firmicutes:Bacteroidetes ratio
 - Characterized by *Lactococcus*

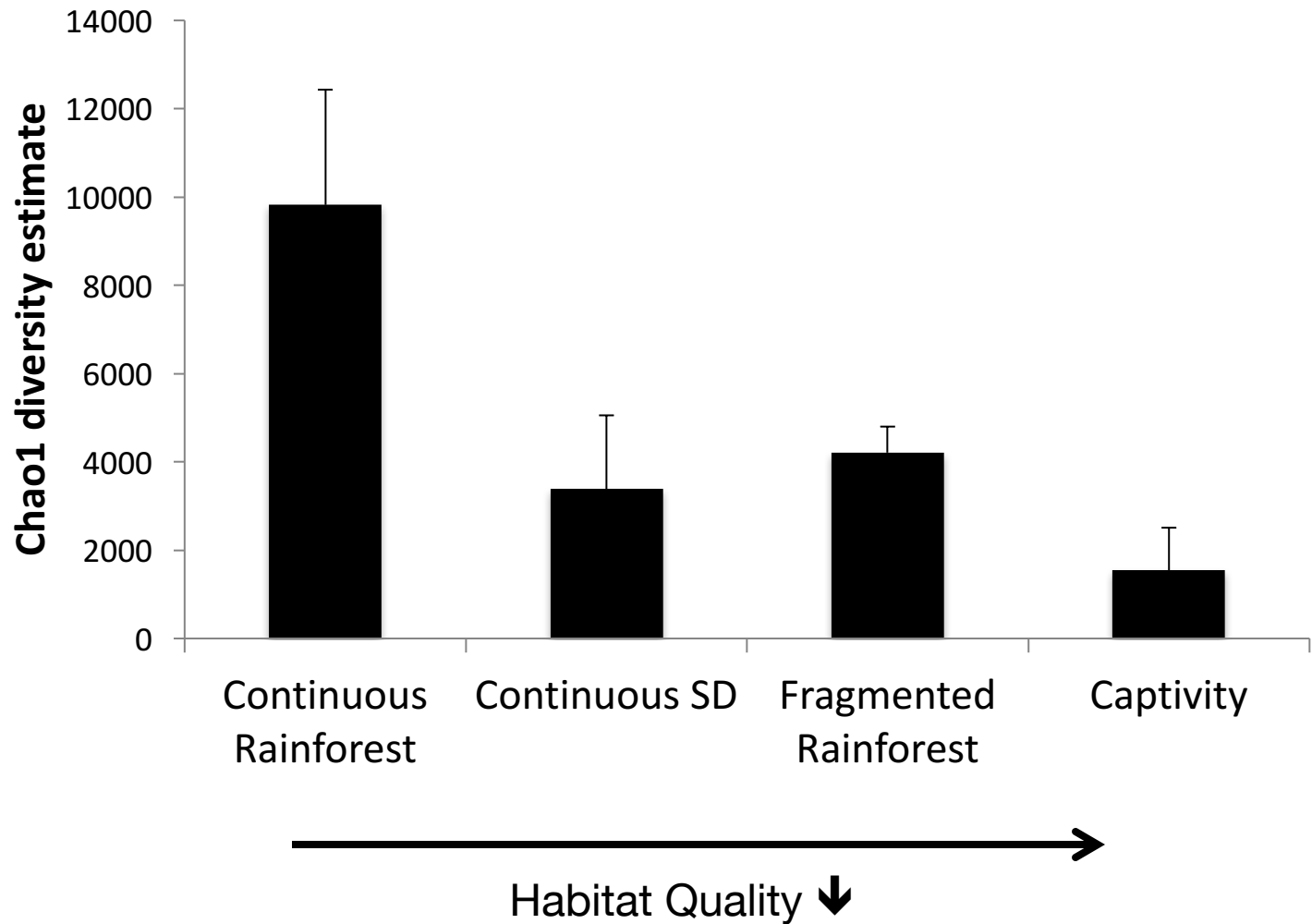


Do these apparently beneficial relationships break down?

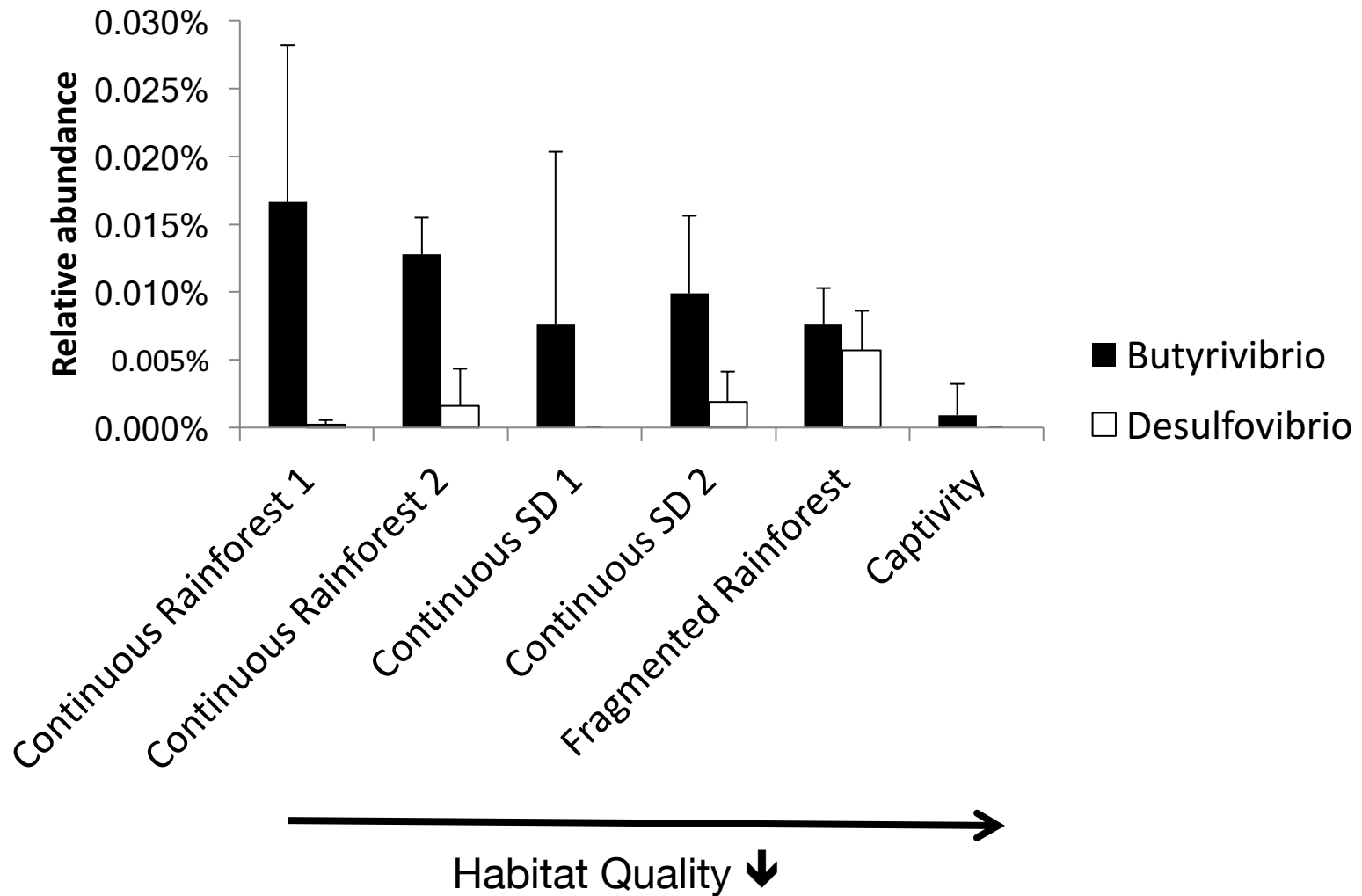
Gut Microbes Degraded With Habitat Disturbance



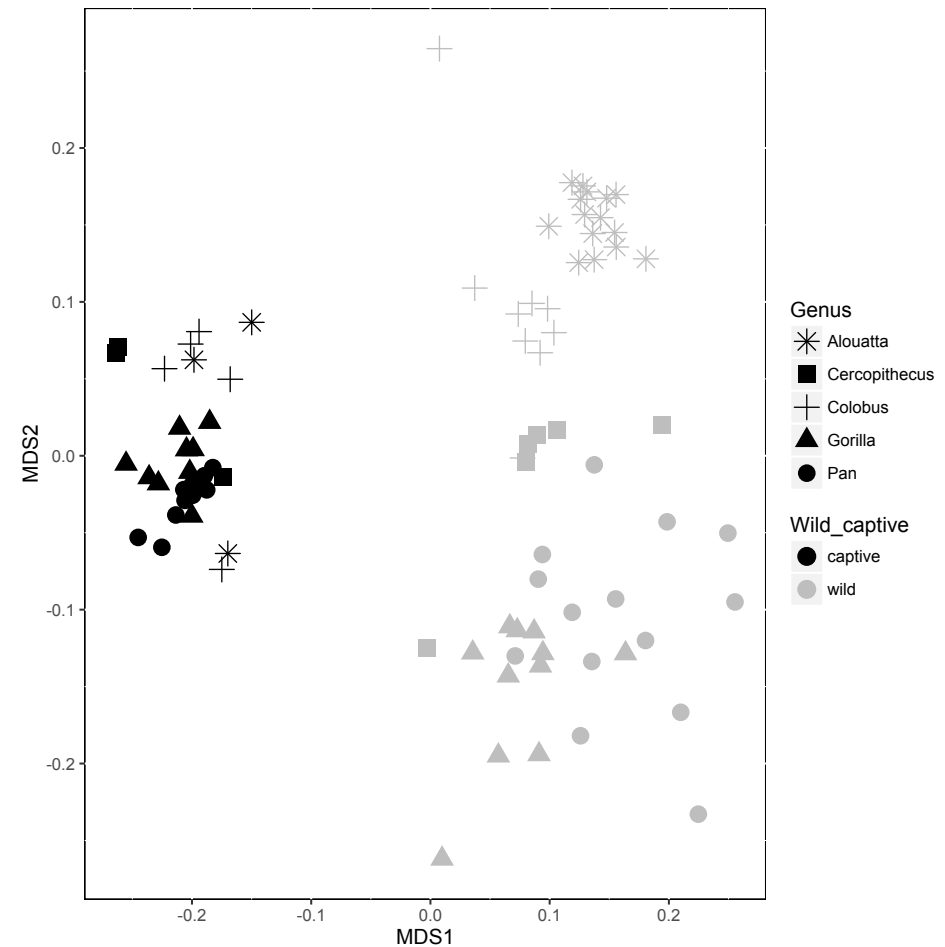
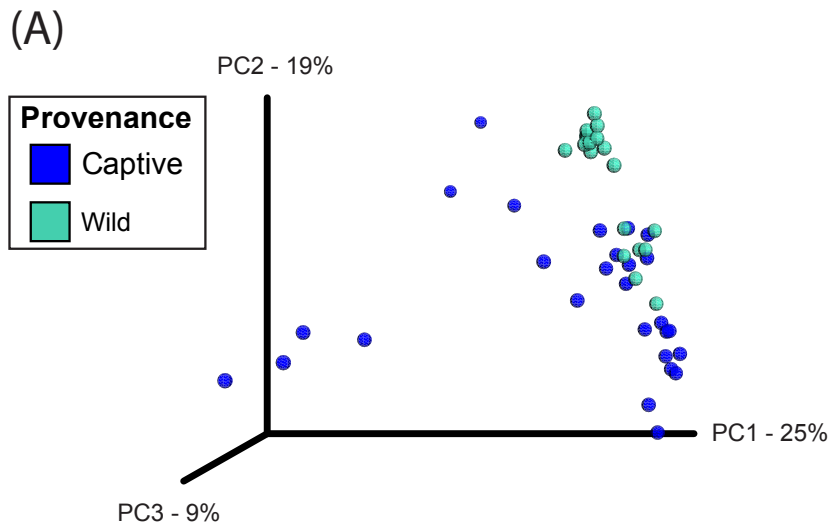
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Gut Microbes Degraded With Habitat Disturbance



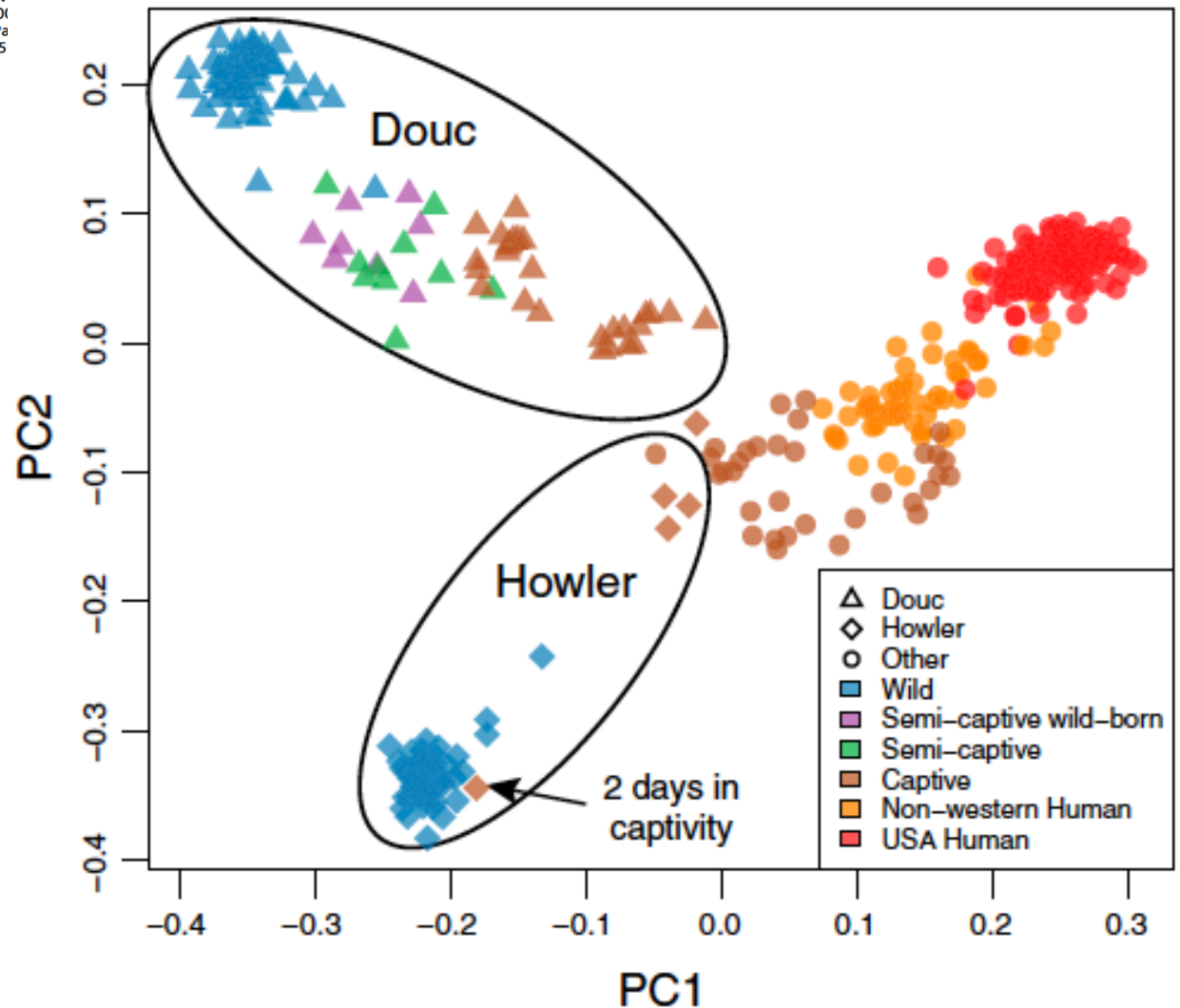
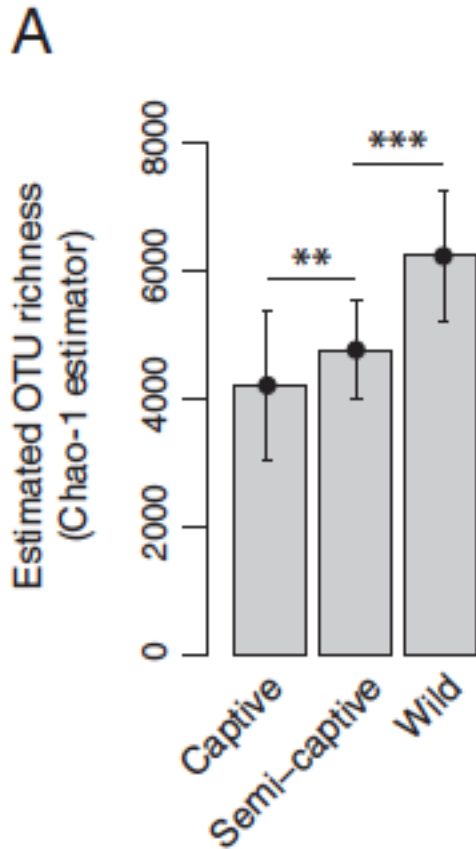
Extreme Case: Captivity in Primates

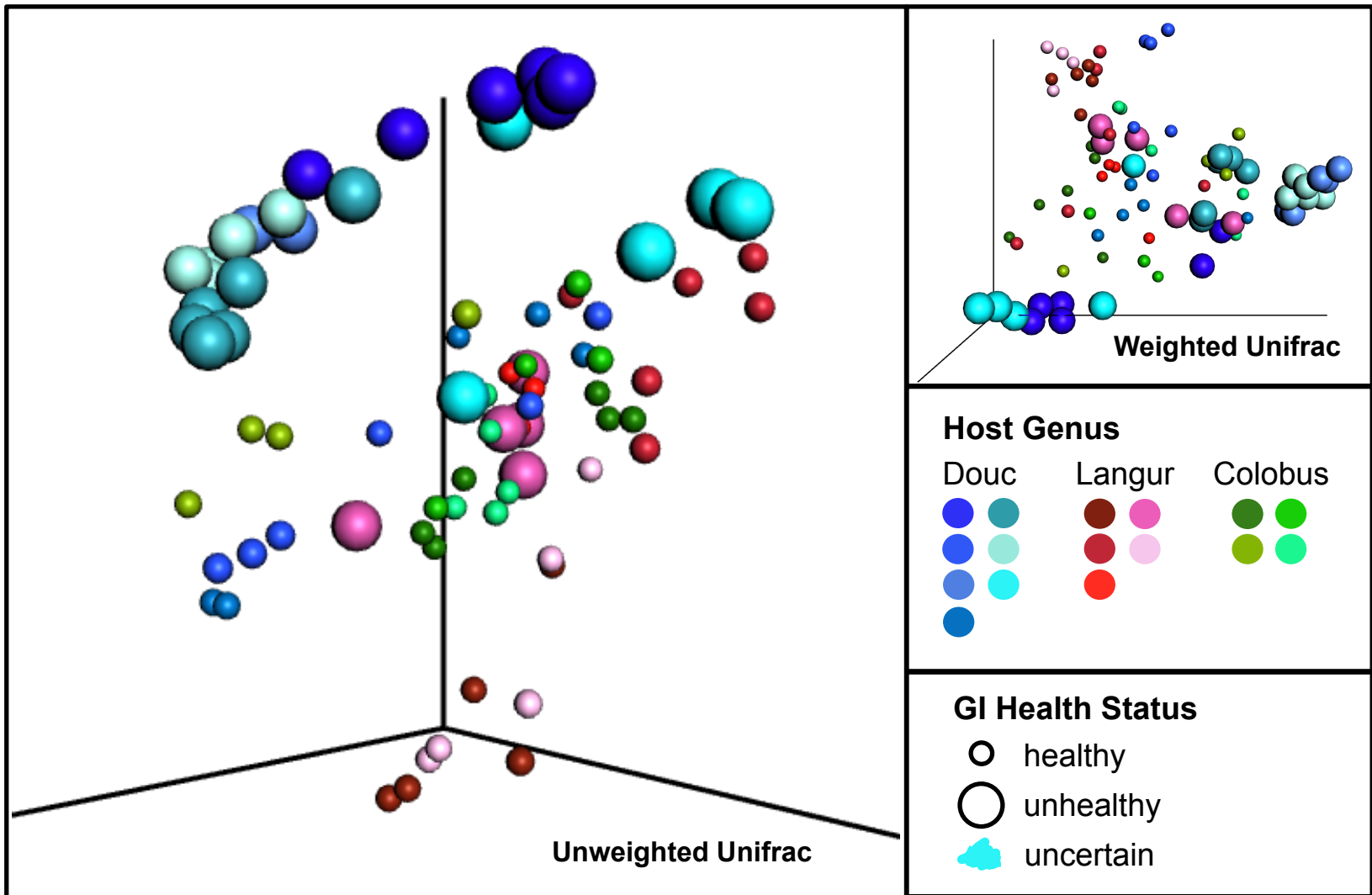


Captivity humanizes the primate microbiome

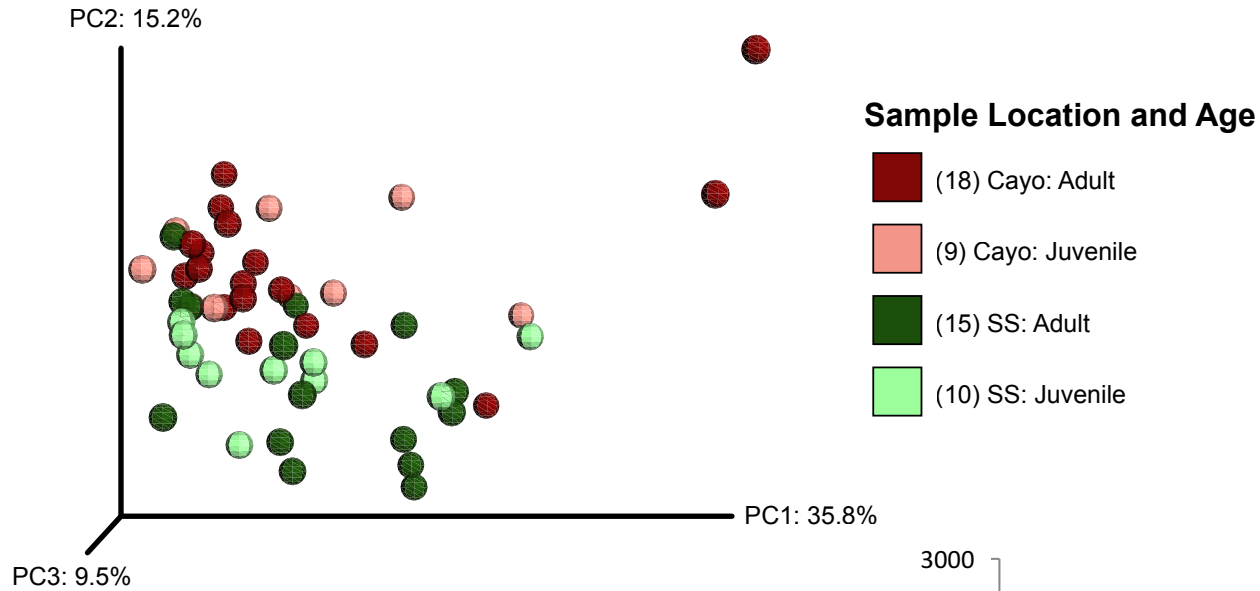
Jonathan B. Clayton^{a,b}, Pajau Vangay^c, Hu Huang^c, Tonya Ward^d, Benjamin M. Hillmann^e, Gabriel A. Al-Ghalith^c, Dominic A. Travis^f, Ha Thang Long^{b,g}, Bui Van Tuan^b, Vo Van Minh^h, Francis Cabanaⁱ, Tilo Nadler^j, Barbara Toddes^k, Tami Murphy^l, Kenneth E. Glander^m, Timothy J. Johnson^a, and Dan Knights^{d,e,1}

^aDepartment of Veterinary and Biomedical Sciences, University of Minnesota, Saint Paul, MN 55108; ^bGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ^cBioinformatics and Computational Biology, University of Minnesota, Minneapolis, MN 55455; ^dRichterichology Institute, University of Minnesota, Saint Paul, MN 55108; ^eDepartment of Computer Science at Veterinary Population Medicine, University of Minnesota, Saint Paul, MN Environment and Biology, Danang University of Education, Danang 59000 Singapore; ^fEndangered Primate Rescue Center, Cuc Phuong National Park, Hanoi, Vietnam; ^gGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ^hGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ⁱGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ^jGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ^kGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ^lGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ^mGreenViet Biodiversity Conservation Center, Danang 59000, Vietnam; ¹Como Park Zoo & Conservatory, Saint Paul, MN 55108

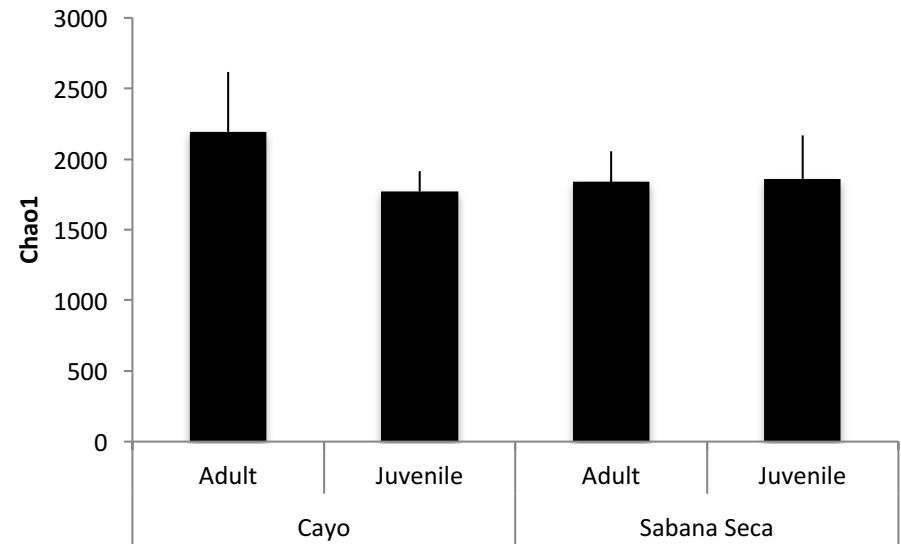




Not just diet...



Weighted UniFrac ($F_{1,51}=5.01$, $r^2=0.09$, $p < 0.01$)





Probably...but we need more data

PLoS One. 2014 Mar 11;9(3):e90731. doi: 10.1371/journal.pone.0090731. eCollection 2014.

Seasonal variation in human gut microbiome composition.

Davenport ER¹, Mizrahi-Man O¹, Michelini K¹, Barreiro LB¹, Ober C¹, Gilad Y¹.

Science. 2017 Aug 25;357(6353):802-806. doi: 10.1126/science.aan4834.

Seasonal cycling in the gut microbiome of the Hadza hunter-gatherers of Tanzania.

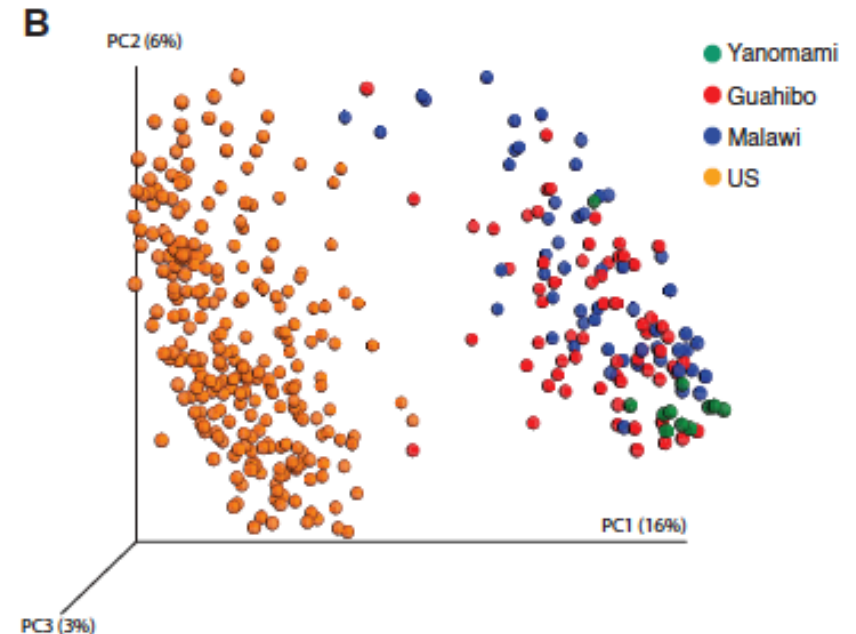
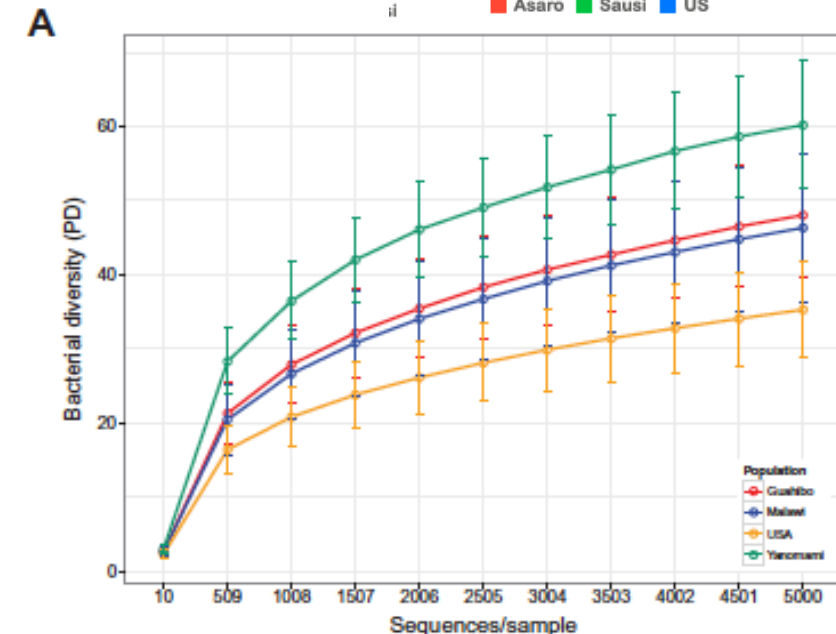
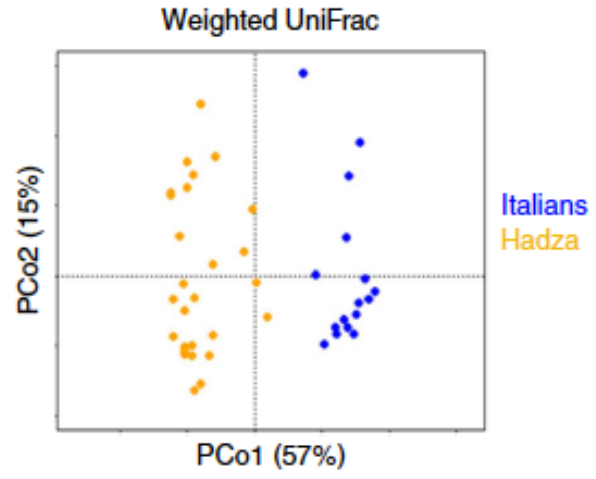
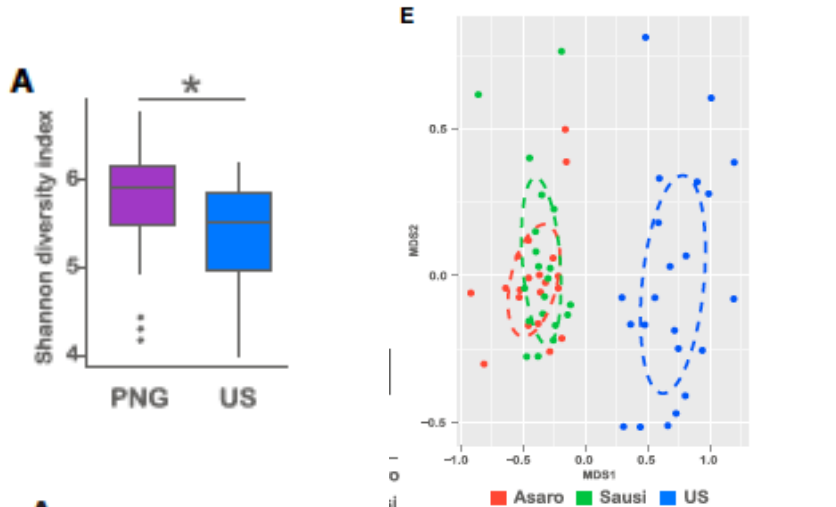
Smits SA¹, Leach J^{2,3}, Sonnenburg ED¹, Gonzalez CG⁴, Lichtman JS⁴, Reid G⁵, Knight R⁶, Manjurano A⁷, Changalucha J⁷, Elias JE⁴, Dominguez-Bello MG⁸, Sonnenburg JL¹.

Cell. 2012 Aug 3;150(3):470-80. doi: 10.1016/j.cell.2012.07.008.

Host remodeling of the gut microbiome and metabolic changes during pregnancy.

Koren O¹, Goodrich JK, Cullender TC, Spor A, Laitinen K, Bäckhed HK, Gonzalez A, Werner JJ, Angenent LT, Knight R, Bäckhed F, Isolauri E, Salminen S, Ley RE.

Industrialization and the Gut Microbiota



What about mismatch situations?

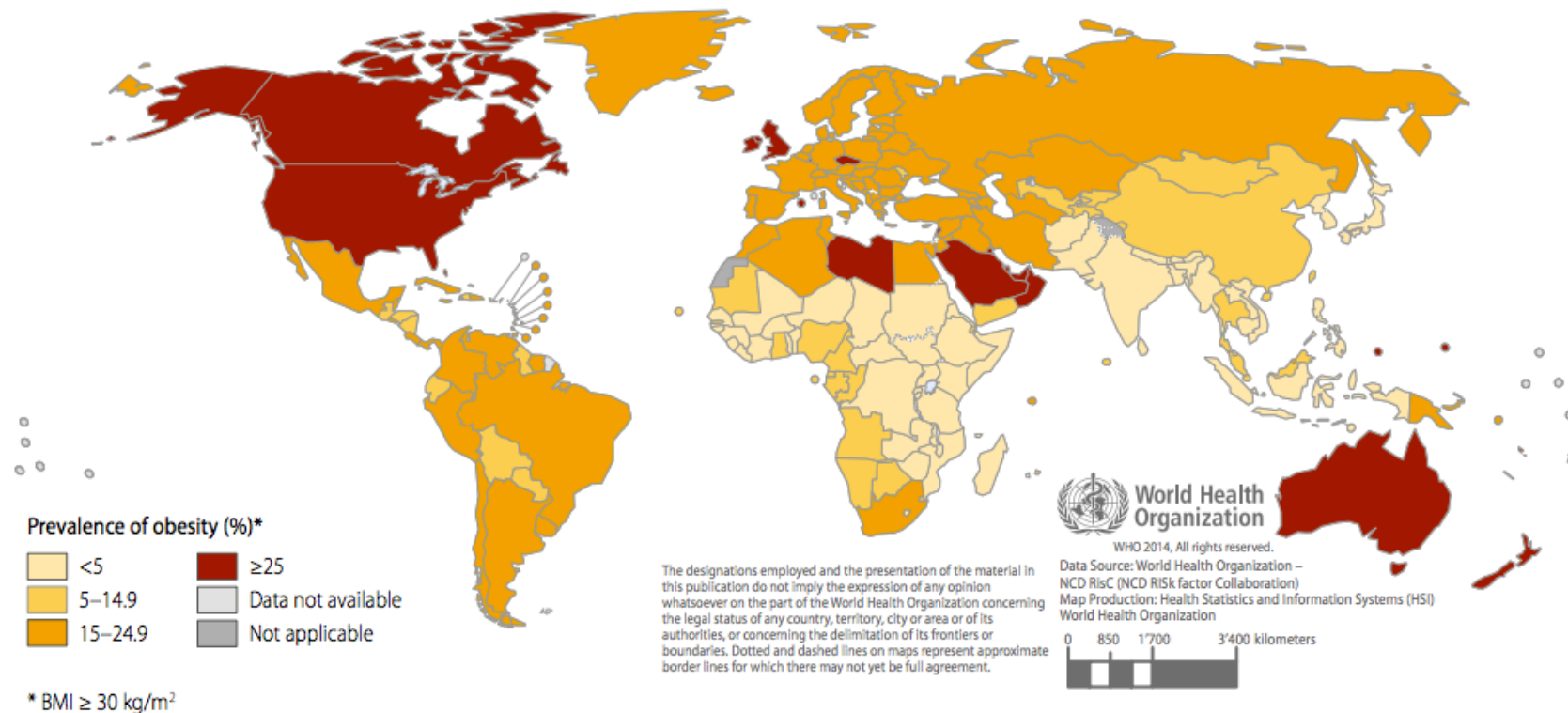
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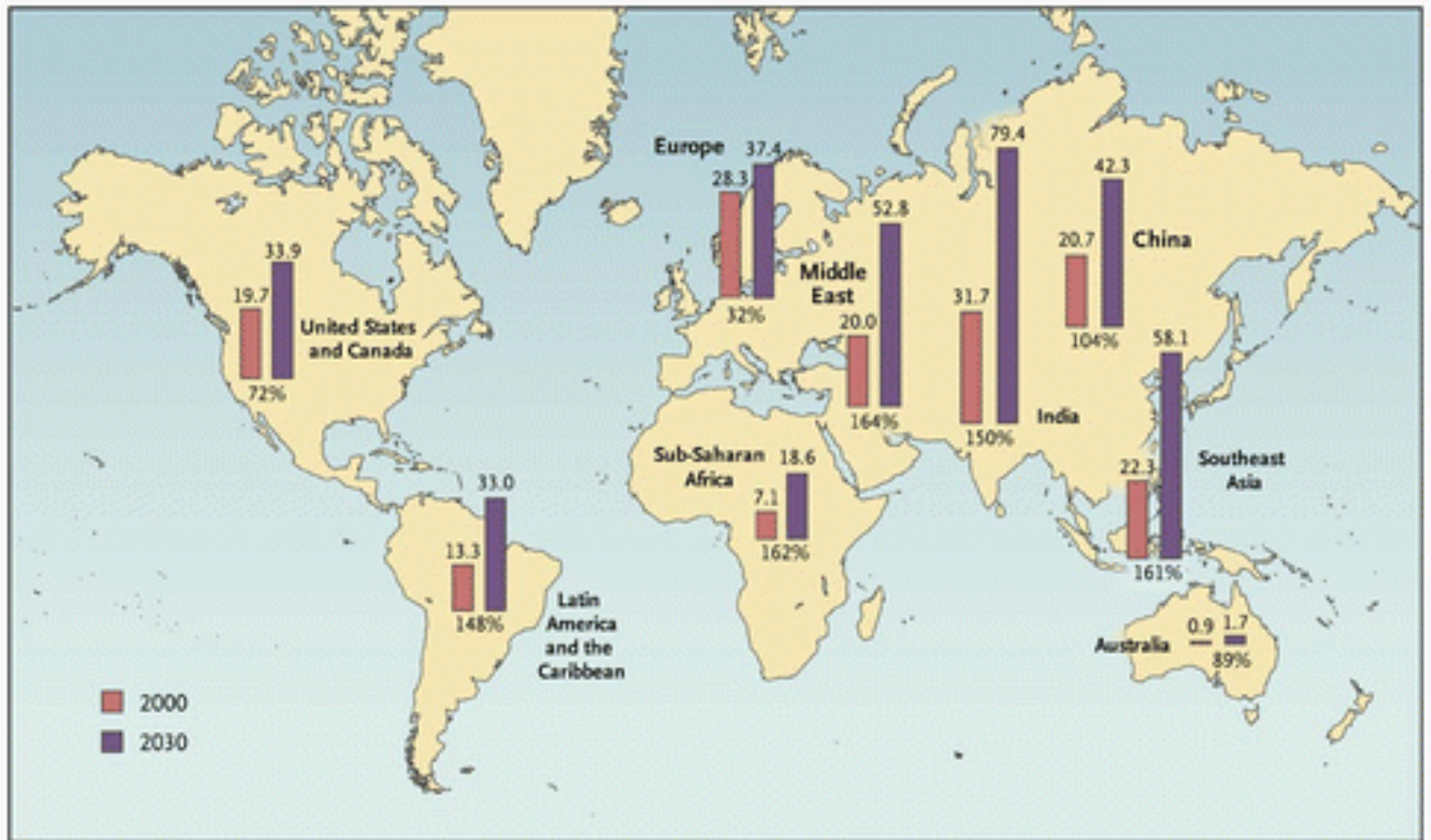
Peter J. Turnbaugh¹, Ruth E. Ley¹, Michael A. Mahowald¹, Vincent Magrini², Elaine R. Mardis^{1,2} & Jeffrey I. Gordon¹





Fig. 7.1 Age-standardized prevalence of obesity in men aged 18 years and over (BMI ≥ 30 kg/m²), 2014

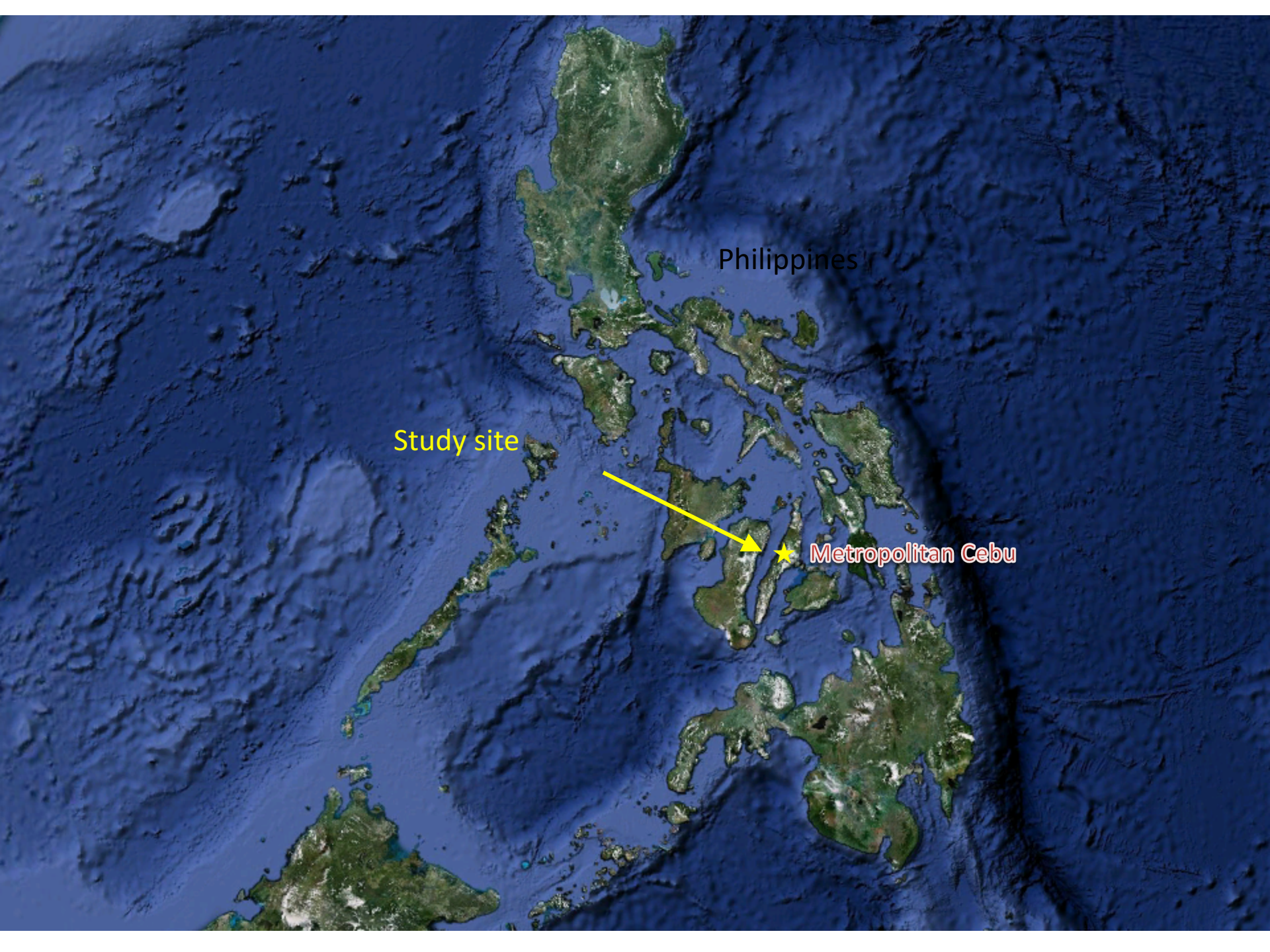






Major Questions

- Does a maternal history of undernutrition in early life lead to a energy-efficient gut microbiota in adulthood?
- Can these microbial traits be passed to infants and affect health outcomes (particularly if the nutritional environment shifts)?



Philippines

Study site

★ Metropolitan Cebu

The Cebu Study

The Cebu Longitudinal Health & Nutrition Survey

3327 pregnant women enrolled (1983)

↓
Birth



Mothers



Offspring

Grandoffspring



1983-4

1984-6



1991



1994



1998-9



2000



2005



2017

preg & birth

infancy

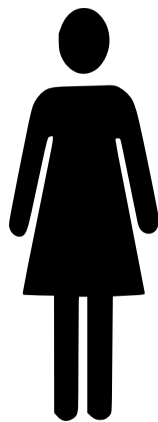
childhood

puberty

young adult

Data collection on full sample

Mom

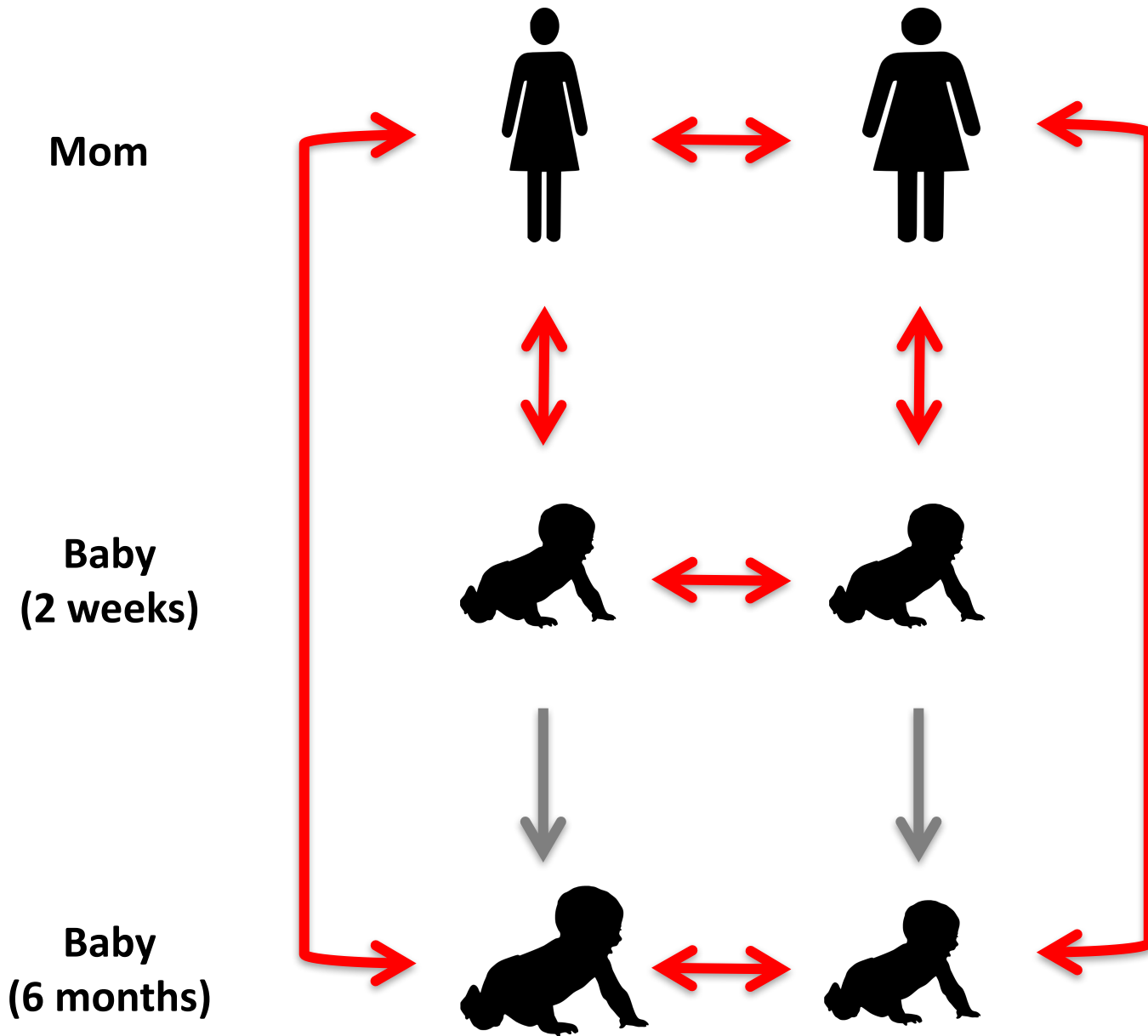


Mom



**Baby
(2 weeks)**





Final Thoughts

- To understand what is ‘wrong’ with the microbiome when there are health issues, we need to:
 - Understand what was evolutionarily ‘right’
 - Understand what perturbations have altered the system
- Studies of human populations are critical
- Non-human primates give us an even broader context

Thank you!

